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An Empirical Model of Pricing in the Catfish Industry

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Abstract *The adoption of aquacultural products has created an imbalance of market power between catfish producers and a processing sector that exerts a monopsonistic power in certain regions of the U.S. such as west Alabama. However, because of the recent changes caused by vertical integration of the catfish industry, the existence of an oligopolistic power has been identified in the catfish industry. An empirical model of pricing in the catfish industry was developed using a theoretical model proposed by Appelbaum. An analysis of the market structure was conducted to provide estimates of conjectural elasticities over time. Conjectural elasticities were used to construct the oligopoly power index. Results show some evidence of the existence of oligopolistic power in the catfish industry that further suggests some degree of price enhancement.*

Keywords catfish industry, pricing, conjectural elasticity, oligopoly power index.

Introduction

Farm-raised catfish has become a large component of the U.S. seafood market. While processors' sales have steadily increased, from 27.8 million pounds in 1980 to 233.5 million pounds in 1993 (a 741% increase) (USDA), farm price of catfish has not followed the same path. Farm price has fluctuated during the 1980–93 period. In 1993, farm price of catfish averaged $71.00 per hundred pounds, a 5% increase from the $67.60 per hundred pounds of 1980, with a low of $55.00 per hundred pounds in 1982 (USDA). However, real prices have mostly declined over the given period.

The adoption of aquacultural products by consumers, especially in the southern states of the U.S., has extended the effects of market forces in the catfish industry. As pointed out by Kinnucan and Sullivan (1986), "a potential problem facing this emerging industry is an apparent imbalance of market power between catfish producers and the processing sector." Recently, some changes have been observed in market conduct due to vertical integration by catfish farmers who exert a degree of market power. Product quality has improved and fluctuations in quantity supplied have been reduced (Nyankori, 1991). These changes have likely led to the existence of oligopolistic power in the catfish industry. However, because of the market forces in place and because of eventual regulation by federal and state agencies, no producer nor processor should be "allowed to raise prices too fast or to achieve excess profits (Taylor and Kilmer, 1988)." The other issue would be that of new entry into the industry. Holloway (1991) studied the effects of potential entry on the long-run performance of food markets. He considered the entry problem in a manner that restricts the persistence of strictly positive profits which were shown to exist in a dynamic setting as suggested by Reynolds (1982).

Recent work have illustrated the uncertainty faced by firms and the implications of market structure on price determination (Shonkwiler and Pagoulatos, 1980; Schroeter, 1988; Holloway, 1991; Schroeter and Azzam, 1991). The purpose of this paper is to provide an analysis of the pricing behavior in the U.S. catfish industry. To achieve the underlined objective, the concept of conjectural variation is used. A conjectural variation measures how a given firm assumes that the price will respond to its change in output. Conjectural elasticities along with indexes of market power derived from the Lerner index are then calculated to conduct the analysis.

A Summary of the Structure of Catfish Industry

The catfish industry is composed of two main sectors which are the production and the processing sectors. Feed as the major input for the production sector constitutes an additional sector to the industry. The complexity of the catfish industry stems from the difference in market conduct between the production and processing sectors.

Literature related to market structure at the catfish production level (Nyankori, 1988; Dillard, 1995; USDA, 1995) have shown the catfish production sector as competitive. Although the catfish production sector satisfies most of the conditions for a competitive industry, one exception may be mentioned that might have caused the industry to depart from perfect competition. As pointed out by Dillard (1995), the cooperative action of producers through the Mississippi Catfish Producers Marketing Association and the Catfish Bargaining Association have had a temporary influence on farm prices, causing a departure from a purely competitive market.

While the production sector is competitive, the processing sector tends toward an oligopolistic structure with few firms producing an homogeneous product. The rivalry that exists between firms in the processing sector, causing such problems as price wars, has made the catfish depart from the perfect competition scenario.

Theoretical Considerations[1]

Consider a non-competitive industry composed of k firms producing a homogenous product, y, using n inputs represented by $x = (x_1, \ldots, x_n)$. The market demand is given by:

$$y = y(p, z) \tag{1}$$

[1] This section is a summary of the theoretical framework presented by Appelbaum (1982) and later summarized by Taylor and Kilmer (1988). While this work is not a duplication of Appelbaum and Taylor and Kilmer's studies, the methodology used follows closely their framework.

where p is the output price, z is a vector of exogenous demand shifters, and $\partial y/\partial p \leq 0$.

Assuming that all firms are price takers in input markets with input price vector $r = (r_1, \ldots, r_n)$, the cost function of the jth firm can be given by:

$$c^j = c_{j(y^j}, r) \tag{2}$$

where y^j is the output of the jth firm.

Two optimization stages are involved in the decision-making process. First, a firm chooses inputs to minimize the cost of producing a given level of output and second, it determines the profit maximizing level of output.

The first optimization process is achieved by defining input demand functions. Input demand functions for the jth firm may be derived from cost functions by applying the Shephard's Lemma,

$$x^j = \partial c^j(y^j, r)/\partial r, \qquad j = 1, \ldots, k \tag{3}$$

where x^j is the input vector of the jth firm and $\partial c^j/\partial r$ is a vector of partial derivatives of c^j with respect to r.

The second optimization process calls for a profit maximization problem of the jth firm,

$$\max[py^j - c^j(y^j, r)/y = y(p, z)] \tag{4}$$

where $y = \Sigma^k_{j=1} y^j$ is the industry supply. The optimality condition is obtained by differentiating (4) with respect to y,

$$p(1 - \theta^j\epsilon) = \partial c^j(y^j, r)/\partial y^j \tag{5}$$

where θ^j is the conjectural elasticity of the jth firm such that,

$$\theta^j = (\partial y/\partial y^j)\,(y^j/y), \tag{6}$$

and ϵ is the inverse price elasticity of demand such that,

$$\epsilon = -(\partial p/\partial y)\,(y/p). \tag{7}$$

Equation (5) states that the optimal output is achieved when perceived marginal revenue equals marginal cost. The conjectural elasticity provides an index of market structure. Comparing equation (5) to models of market structure, one can define various cases depending upon the value of θ^j. For example, (1) in case of perfect competition, $\theta^j = 0$: the firm believes that price will not change due to a change in output; (2) when $\partial y/\partial y^j = 1$, a Cournot behavior prevails and $\theta^j = 1$ under pure monopoly. y^j/y gives the reactions of the rest of the industry to the given firm's output choice. It can be inferred from the preceding that the value of θ^j is bounded such that $0 \leq \theta^j \leq 1$.

Following Holloway (1991), equation (5) can be modified to show that θ can be considered as the "weight" in a convex combination of the average and marginal revenues facing the industry as shown in Figure 1. While allocative decisions in

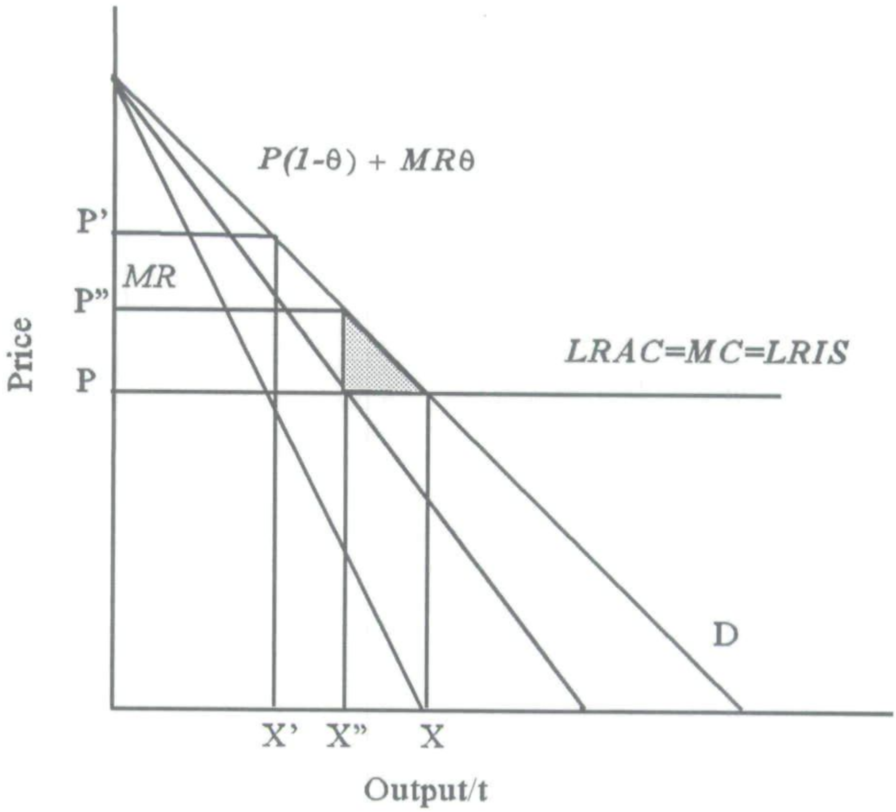

Figure 1. Simplified Oligopoly Equilibrium: The Cournot Model. A duopolist in the Cournot model will set prices of P "with output X" lower than those chosen by a monopolist that charges a price of P′ with a quantity of X′, but higher than those for a firm in perfect competition that charges a price of P with a quantity of X.

the case of perfect competition depend on average revenues, these decisions depend on both the average and marginal revenues in cases of oligopoly.

The striped area in Figure 1 increases with the value of θ and represents the deadweight loss resulting from noncompetitive behavior. This component of market performance is closely related to the value of the conjectural elasticity. In fact, it follows from equation (5) that inferences about market performance can be made by taking a monotonic transformation of θ. Such a transformation can lead to the definition of the Lerner index, which measures the distortion in price that is attributable to market power. A degree of oligopoly power of the jth firm can then be defined as:

$$\alpha^j = [p - \partial c^j(y^j, \mathrm{r})/\partial y^j]/p = \theta^j\epsilon \tag{8}$$

Appelbaum showed that α^j is also bounded by zero and one. A generalization of (8) is carried out to obtain the industry measure of oligopoly power such that,

$$L = \Sigma_j \alpha^j S_j \tag{9}$$

where S_j is the share of industry attributable to the jth firm. This measure of oligopoly power is viewed as a weighted sum of each firm's output share multiplied by its oligopoly power index. L is basically a generalization of the Lerner index.

Because of the non-existence of individual firm data, an aggregate version of the model can be used to calculate oligopoly power for the "typical" firm. As with most aggregate models, it is necessary to define certain conditions in order to get consistent results. In the present case, an aggregated model is obtained by assuming that, in equilibrium, all firms have the same marginal cost and perceived marginal revenue. This leads to assuming that all firms have the same equilibrium conjectural elasticity. As long as equilibrium exists, the aggregate industry cost function, $c(y, r)$, enables us to write the aggregate optimality conditions as:

$$p(1 - \theta\epsilon) = \partial c(y, r)/\partial y, \tag{10}$$

where θ is the equilibrium conjectural elasticity.

Empirical Model

Following Appelbaum (1982) and Taylor and Kilmer (1988), the demand function facing the catfish industry is specified as a double-log function such that:

$$lnY = a - \eta ln(p/I) + \rho ln(m/I) \tag{11}$$

where Y is the quantity of catfish sold by processors; p is wholesale price of fish; I is the CPI used as deflator; and m is per capita income. The constant demand elasticity is given by $\eta = 1/\epsilon$.

The industry cost function is expressed as a generalized Leontief cost function such that:

$$c = \Sigma_i\Sigma_j b_{ij}(r_ir_j)^{1/2}Y + \Sigma_i b_i r_i, \qquad i, j = L, F, Q \tag{12}$$

where $b_{ij} = b_{ji}$; r is input cost; and L is labor, F is feed, and Q is quantity of catfish, round-weight processed. θ is allowed to vary over time, reflecting changes in the economic environment.

The full model for the catfish industry is then given by:

$$\begin{aligned}
L &= b_{LL} + b_{FL}(r_F/r_L)^{1/2} + b_{LQ}(r_Q/r_L)^{1/2} + b_L/Y,\\
F &= b_{FF} + b_{FL}(r_L/r_F)^{1/2} + b_{FQ}(r_Q/r_F)^{1/2} + b_F/Y,\\
Q &= b_{QQ} + b_{LQ}(r_L/r_Q)^{1/2} + b_{FQ}(r_F/r_Q)^{1/2} + b_Q/Y,\\
lnY &= a + \eta ln(p/I) + \rho ln(m/I),\\
p &= [p_{LL}r_L + b_{FF}r_F + b_{QQ}r_Q + 2b_{FL}(r_Fr_L)^{1/2} + 2b_{LQ}(r_Lr_Q)^{1/2}\\
&\qquad + 2b_{FQ}(r_Fr_Q)^{1/2}]/(1 - \theta/\eta)
\end{aligned}$$

where θ is approximated linearly as $\theta = a_0 + a_Lr_L + a_Fr_F + a_Qr_Q$.

The model is estimated as a simultaneous non-linear system of equations using the full information maximum likelihood method. The maximum likelihood estimates are then used to calculate the conjectural elasticities and degree of oligopoly power. The market structure is identified by conducting a test of significance of θ.

The model is estimated using annual aggregate data for the period of 1977–93. Data on quantity and price of fish were obtained from various issues of the USDA "Aquaculture: Situation and Outlook Report." Data for feed price and quantity were obtained from various issues of the USDA "Feed: Situation and Outlook Report" and from various publications by the Mississippi Extension Service. Data related to the Consumer Price Index (CPI), labor cost, and income were obtained from various issues of the Business Conditions Digest. Results obtained by Appelbaum (1980) for the textile, rubber, electrical machinery, and tobacco industries and Taylor and Kilmer (1988) for the celery industry are used as basis of comparison for the level of oligopolistic power and market structure.

Results and Discussion

Estimated parameters are given in Table 1. As is often pointed out, estimating a non-linear system of equations is tedious and generates considerable output. The main problem encountered with non-linear systems is to define the starting values to obtain consistent estimates. In the present case, the model was estimated one hundred times with different starting values until the estimates became stable and converged to the same values. Most of the estimated parameters were significant at the 5% level.

Table 1
Parameter Estimates

	Unrestricted Model		Restricted Model	
Parameter	Coefficient	St. Error	Coefficient	St. Error
b_{LL}	15.690*	3.2446	2.158*	1.0266
b_{FL}	0.900	0.5245	2.631*	0.5510
b_{LQ}	0.154	1.0988	−0.004	0.5385
b_L	2.579*	1.4042	1.179	1.1183
b_{FF}	0.890*	0.3823	−0.229	0.1486
b_{FQ}	−0.124	0.1565	−0.073	0.0666
b_F	6.639*	0.7261	6.899*	0.6558
b_{QQ}	−0.981	1.1272	1.073*	0.1890
b_Q	3.017*	1.1315	0.915*	0.1841
a	−26.302*	3.3023	−21.401*	2.6173
η	−1.175*	0.1795	−1.322*	0.2263
ρ	2.226*	0.1958	1.950*	0.1564
a_0	1.049*	0.3629	—	—
a_L	−1.556*	0.6537	—	—
a_F	0.450*	0.1855	—	—
a_Q	−12.361*	4.5680	—	—

Unrestricted versus restricted model
Calculated $\chi^2 = 15.39$
$\chi^2(4)_{.01} = 13.3$

* Indicates significance at the 5% level.

As stated by Taylor and Kilmer (1988), the main concern with the use of dual functions in the estimation process is whether or not results are consistent with the regularity conditions implied by production theory. Both symmetry and homogeneity conditions were imposed. Therefore, only monotonicity and concavity needed to be tested.

Following Appelbaum (1982) and Taylor and Kilmer (1988), monotonicity was tested by evaluating the estimated input demand functions. The predicted values obtained from the estimated labor, feed, and quantity of fish processed functions were all positive, indicating that monotonicity was satisfied over the closed set defined by the data.

By definition, concavity of the cost function would be achieved if the Hessian matrix is negative semi-definite. For the cost function considered in the model, a sufficient condition for global concavity is that $b_{ij} \geq 0$ for all $i \neq j$. This condition was violated by the values of b_{fq} in the unrestricted model and b_{lq} in the restricted model. However, since these values were small and not statistically significant at the 5 percent level, it is "safe" not to reject the concavity of the cost function.

To identify the market structure, the hypothesis $\theta = 0$ was tested. A sufficient condition for $\theta = 0$ is that $a_0 = a_L = a_F = a_Q = 0$. However, it should be noted that this condition is sufficient but not necessary. A restricted model where $a_0 = a_L = a_F = a_Q = 0$ was then run to complete the test. Results are summarized in Table 1. The χ^2 statistics indicates that the hypothesis $\theta = 0$ is rejected for the catfish industry, suggesting a non-competitive market. However, the rejection of the null hypothesis does not constitute a non-refutable proof of the absence of competitive pricing behavior. Some other combinations of the a_i's may cause $\theta = 0$. The hypothesis tested did not account for such cases.

To measure the degree of competitiveness of the catfish industry, information on the oligopoly power index alone is not sufficient. It is important to know the demand elasticity in order to determine the degree of competition in the industry. Since $L = \theta/\eta$, the deviation from l/η provides additional information on market structure. As pointed out by Appelbaum (1980), different demand conditions will lead to different oligopoly power measures, even if the degree of competition remain unchanged. The own price elasticity of demand, η, of -1.17 indicated an elastic demand of processed catfish and was statistically significant at the 5% level. This result is consistent with previous findings (Kinnucan *et al.* 1988; Zidack *et al.* 1992).

The estimated conjectural elasticities and oligopoly power for the period of the study are given in Table 2. The magnitude of the conjectural elasticities along with the oligopoly power indexes and the elastic demand suggest a departure from the perfect competition market structure. The oligopoly power measures of the catfish industry are higher than those obtained by Appelbaum for the rubber, textile, and electrical machinery industries, but lower than those obtained for the tobacco industry. Appelbaum (1980) estimated average oligopoly power indexes of 0.0559, 0.0671, 0.1960, and 0.6508 for the rubber, textile, electrical machinery, and tobacco industries, respectively. These results suggested that the rubber and the textile industries were competitive, while the electrical machinery and the tobacco industries were non-competitive. Results reported by Taylor and Kilmer (1988) showed that the Florida celery market was non-competitive with an average oligopoly power index of 0.24677, and a low elasticity of demand of -0.42.

Although no strong evidence is provided, some degree of price enhancement

Table 2
Estimated Conjectural Elasticities and Oligopoly Power Indexes

	Conjectural Elasticity		Oligopoly Power Index	
Year	Value	St. Error[1]	Value	St. Error[1]
1977	0.42030	0.48529	0.35804	0.50181
1978	0.57045	0.45218	0.48595	0.46758
1979	0.52984	0.46739	0.45135	0.48330
1980	0.44530	0.44986	0.37933	0.46517
1981	0.70898	0.45613	0.60395	0.47167
1982	0.77452	0.47012	0.65978	0.48613
1983	0.73507	0.48796	0.62617	0.50457
1984	0.55710	0.44141	0.47457	0.45644
1985	0.27770	0.47632	0.23656	0.49253
1986	0.37674	0.43641	0.32093	0.45127
1987	0.47830	0.44048	0.40744	0.45547
1988	0.48255	0.42365	0.41106	0.43808
1989	0.48355	0.44151	0.41192	0.45655
1990	0.36559	0.44480	0.31143	0.45994
1991	0.49295	0.44881	0.41992	0.46409
1992	0.58208	0.44872	0.49585	0.46400
1993	0.51345	0.43424	0.43739	0.44903
Mean	0.51732	0.13189	0.44069	0.11235

[1] St. Error indicates the asymptotic standard errors.

is implied, especially in the early 1980's when the oligopoly power index was greater than 0.50. This may be attributed to the rapid growth of the catfish industry with a high degree of market concentration. This is coupled with the fact that only a few of the reporting processing firms handled more than 90 percent of the total pounds processed in the early 1980's (Miller *et al.* 1981). Although the degree of concentration may have declined, it has been recently reported that the processing sector remains somewhat concentrated, with a four-firm concentration index ranging between 60–70 percent (Dillard). As suggested by Taylor and Kilmer (1988) for the Florida celery market, another possible explanation to the high degree of price enhancement in the early 1980's is due to the fact that the industry was still going through a learning process. As more processors enter the market and as farmers integrate vertically to fight the ''too powerful'' processing sector, the degree of price enhancement tends to stabilize at a lower level, as seen in recent years. Although results suggest that the catfish industry is oligopolistic, it is still necessary to prove whether or not conjectural elasticities and oligopoly power indexes constitute a definitive proof of a departure from perfect competition. However, from the trends observed with the present results, it may be possible to anticipate a movement toward a more competitive market.

Conclusions

The objective of this paper was to determine to what extent price distortion exists in the catfish industry. The results obtained provide a measure of oligopolistic power that suggests the existence of some degree of price enhancement in the catfish industry. However, the question of excessive price enhancement still needs further investigation. While point estimates of the conjectural elasticities and the oligopoly power indexes were not statistically significant, their mean values were significant at the 5 percent level, suggesting that overall the industry has behaved as a non-competitive one. Recent trends in the industry and new entrants may lead to a more competitive structure. Because the pricing behavior of the industry depends heavily on the structure of supply, efforts should be directed toward defining cost and production functions that would capture the impacts of the supply structure to provide a better understanding of catfish market power.

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